

Field Methods for Studying the Colorado River Fishes in Grand Canyon National Park

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Abstract. Field investigations were initiated in October 1990 to study the ichthyofauna of the Colorado River in Grand Canyon National Park with emphasis on the life history and ecology of the endangered humpback chub (*Gila cypha*). These investigations were part of the environmental studies to evaluate the operation of Glen Canyon Dam. Small maneuverable research boats, modified fish sampling methods, and radiotelemetry were evaluated for continued use in this fishery investigation. Small research boats increased access from established base camps to sample sites, both up- and downstream, providing more thorough sampling coverage. These small boats required skilled handlers and were used for electrofishing, to set and retrieve fish sampling gears, and to recontact radio-tagged fish. Electrofishing, gill and trammel nets, hoop nets, minnow traps, and seines were adapted for use in riverine and whitewater habitats to assess relative abundance, distribution, and habitat use of fishes of all ages. Radiotelemetry was used to monitor movement and habitat of adult humpback chub, although signal strength was limited by water depth, specific conductance, and canyon geologic features. We demonstrated that small research boats, modified fish sampling methods, and radiotelemetry are effective in whitewater regions, such as the Colorado River in Grand Canyon, as aids to better understand the ichthyofauna of these little-known regions.

Key words: Colorado River fishes, electrofishing, fish sampling gears, Grand Canyon National Park, humpback chub, research boats.

We evaluated fish sampling methods implemented in a study of the ichthyofauna of the Colorado River in Grand Canyon National Park. The

investigation was conducted as part of the Glen Canyon Environmental Studies (GCES) to evaluate the effects of the operation of Glen Canyon Dam on native fishes, particularly the endangered humpback chub (*Gila cypha*). This methods evaluation was conducted during the first phase of the field study—October 1990 through November 1991. Small research boats, modified fish sampling methods, and radiotelemetry were evaluated for their efficiency and potential for continued use in Grand Canyon.

Whitewater canyon regions of the Colorado River basin have, until recently, been some of the least intensively sampled areas in the basin. Ichthyofaunal surveys and investigations have been delayed because these areas are remote and difficult to access and travel and because conventional fish sampling gears can be ineffective. Recent surveys of whitewater regions under the jurisdiction of the National Park Service have shown that these areas harbor some of the last remaining populations of the endemic and federally listed endangered fishes: Colorado squawfish (*Ptychocheilus lucius*), humpback chub, bonytail (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*). Humpback chub, Colorado squawfish, and razorback sucker occur in Yampa Canyon of Dinosaur National Monument (Karp and Tyus 1990) and in Cataract Canyon of Canyonlands National Park (Valdez 1990). The largest population of humpback chub inhabits the Colorado River of Grand Canyon National Park (Carothers and Minckley 1981; Kaeding and Zimmerman 1982). Humpback chub, Colorado squawfish, and razorback sucker are also found in other canyon regions including Black Rocks, Westwater Canyon, and Desolation and Gray canyons (Valdez and Clemmer 1982), all under Bureau of Land Management jurisdiction. Bonytail were recently captured in Black Rocks (Kaeding et al. 1986), Desolation and Gray canyons (M. Moretti, Utah Division of Wildlife Resources, Price, personal communication), and Cataract Canyon (Valdez 1990).

The Colorado River basin is a particularly difficult ecosystem for conducting ichthyofaunal investigations. The rivers in this basin are accessible from few points, some located hundreds of kilometers apart. Fish sampling can be difficult because river flow varies dramatically by season, and high spring flows from snowmelt can increase volume 10- to 20-fold (e.g., the Colorado River increased from 200 to 2,000 m³/s in 1986). Daily flow fluctuations below hydropower dams—such as Flaming Gorge on the Green River and Glen Canyon Dam on the Colorado River—make travel difficult, dramatically alter fish habitats, and can inundate or strand fish sampling gears. Turbidity varies dramatically and can impede sampling by altering fish behavior, reducing visibility for electrofishing, and varying conductivity that affects electrofishing efficiency. Swift and turbulent rapids compound sampling difficulty by impeding travel and limiting sampling opportunities. No treatise exists on use of specialized research boats, modified fish sampling methods, or radiotelemetry in whitewater canyon regions.

New methods were developed and implemented in other whitewater regions of the Colorado River basin (Valdez et al. 1982; Valdez 1990) and

were introduced into the Grand Canyon to enable biologists to better cope with the difficult sampling conditions. The methods were designed to facilitate whitewater ichthyofaunal surveys and to examine the life history and ecology of the fishes, particularly the native and endangered species.

Study Area

We conducted the evaluation in 275 km of the Colorado River in Grand Canyon (Fig. 1) from Kwagunt Rapid at river kilometer (RK) 91 to Diamond Creek (RK 366). We used a stratified random sampling design. The study area was stratified longitudinally into three reaches including reach 1—Kwagunt Rapid (RK 91) to Red Canyon (RK 124); reach 2—Red Canyon to Havasu Creek (RK 254); and reach 3—Havasu Creek to Diamond Creek (RK 366). Each reach was subdivided into strata based on the categorization of geomorphology of the Grand Canyon by Schmidt and Graf (1988). We randomly selected from these geomorphic strata to ensure an approximately even distribution of sample effort and to provide equal opportunity for sampling various fish habitats, as determined by geologic features and shoreline types.

Research Boats

The sport utility SU-16 (4.9 m long) and sport heavy-duty SH-170 (5.2 m long) boat models were used. The Hypalon inflatable boats were manufactured by Achilles Corp. (Number 22 Daikyo-Cho, Shinjuku-Ku, Tokyo 160). The model SU-16 boat was used for electrofishing, and the model SH-170 was used for netting and radiotracking. Each was powered by a 40-horsepower Yamaha outboard motor. The boats have been used as recreational river craft on the Colorado River since the early 1980's. A model SH-170 was first used for whitewater fishery research in Cataract Canyon in 1987 (Valdez 1990).

The model SU-16 boat was selected for electrofishing because the square bow provided more room for netters in the front compartment than the model SH-170. A two-piece electrofishing frame was constructed (Fig. 2); it consisted of a front subframe with deck and safety railing for netters and a rear subframe for a live well, generator, fish processing kit, spare tools, first aid kit, raft repair kit, and waterproof boxes for cameras, fathometers, and electrofishing components. Lights for nighttime electrofishing were attached to the front railing and powered by the generator. The boat was steered and shifted manually to reduce weight and space occupied by remote controls.

The model SH-170 boat was used for setting and checking nets and for radiotracking. This boat had a tapered bow, unlike the square bow of the model SU-16, but we noted no difference in boat performance. A one-piece

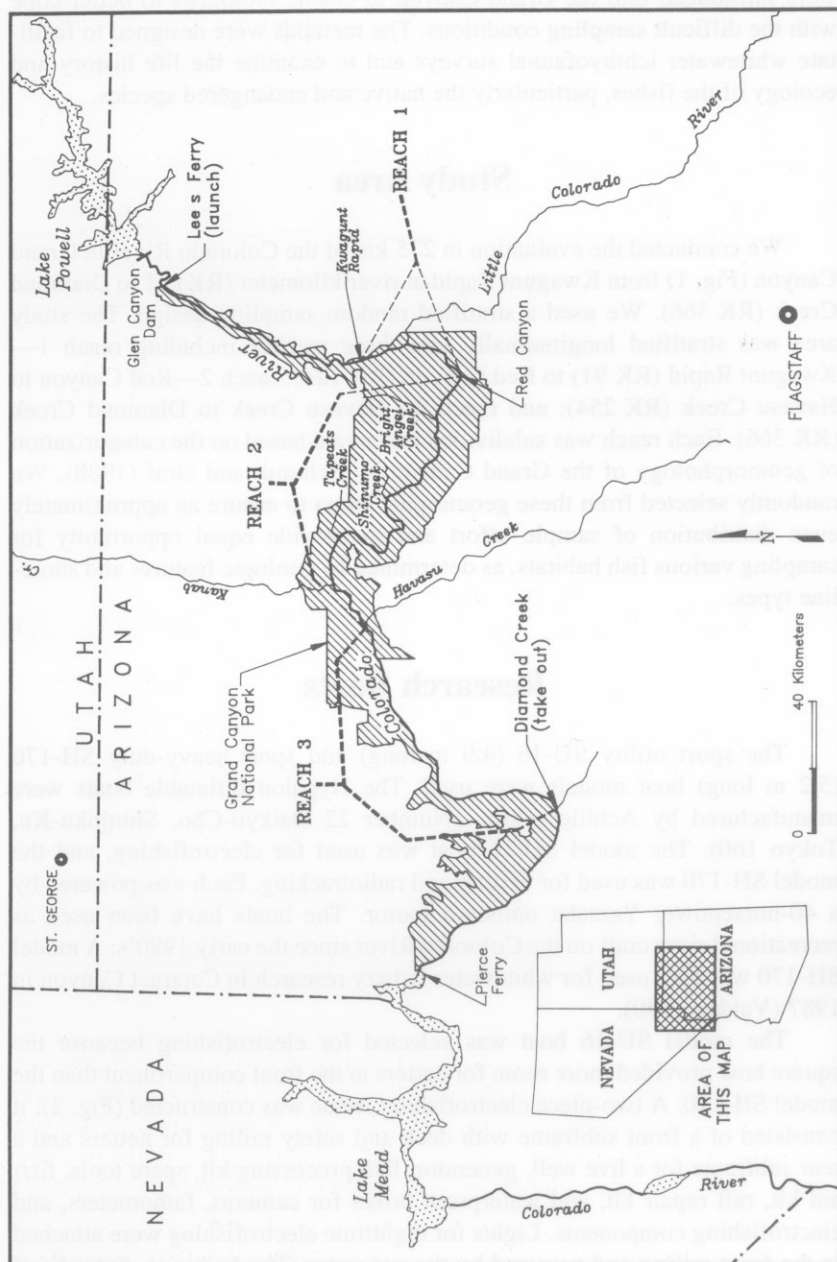


Fig. 1. The three study reaches of the Colorado River in Grand Canyon National Park.

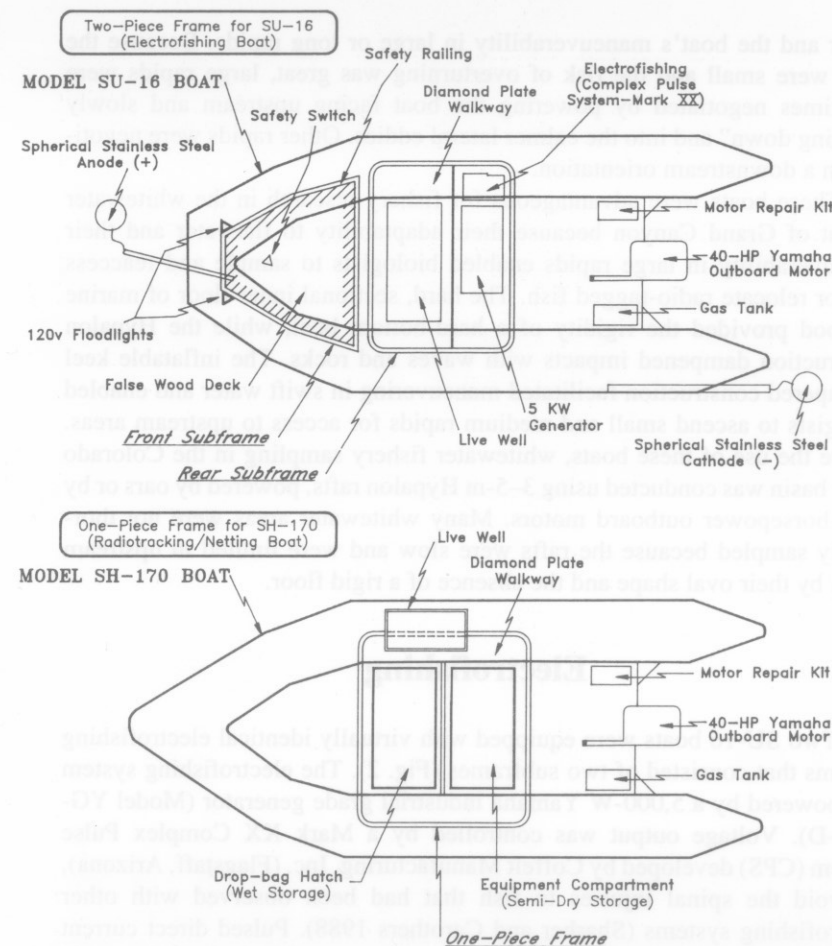


Fig. 2. Frame designs for the model SU-16 and SH-170 research boats.

frame was constructed for each SH-170 boat (Fig. 2) with drop-bag hatch for wet storage and an equipment compartment for semi-dry storage. The same safety and repair kits itemized for the SU-16 boat were included in each SH-170 boat. A live well for holding fish was tied to the top of the diamond plate walkway. Fathometers were used on each boat to record depth contours associated with radio-tagged fish and to presurvey bottom contours for setting nets and electrofishing. Research boat frames were designed so that all items on board were secured or tied to prevent equipment loss and to minimize personal hazard during travel, normal use, and in case a boat was overturned in rapids.

Skilled handlers with a thorough knowledge of whitewater rafting techniques were required to operate these boats. Hazards were avoided by using

power and the boat's maneuverability in large or long rapids. Because the boats were small and the risk of overturning was great, large rapids were sometimes negotiated by powering the boat facing upstream and slowly "backing down" and into the calmer lateral eddies. Other rapids were negotiated in a downstream orientation.

These boats were advantageous for fishery research in the whitewater habitat of Grand Canyon because their adaptability to flatwater and their maneuverability in large rapids enabled biologists to sample and reaccess sites or relocate radio-tagged fish. The hard, sectional inner floor of marine plywood provided the rigidity of a hard-bottom boat, while the Hypalon construction dampened impacts with waves and rocks. The inflatable keel and tapered construction facilitated maneuvering in swift water and enabled biologists to ascend small and medium rapids for access to upstream areas. Before the use of these boats, whitewater fishery sampling in the Colorado River basin was conducted using 3–5-m Hypalon rafts, powered by oars or by 5–25-horsepower outboard motors. Many whitewater areas were not thoroughly sampled because the rafts were slow and were limited in upstream travel by their oval shape and the absence of a rigid floor.

Electrofishing

Two SU-16 boats were equipped with virtually identical electrofishing systems that consisted of two subframes (Fig. 2). The electrofishing system was powered by a 5,000-W Yamaha industrial grade generator (Model YG-5000-D). Voltage output was controlled by a Mark XX Complex Pulse System (CPS) developed by Coffelt Manufacturing, Inc. (Flagstaff, Arizona), to avoid the spinal injuries to fish that had been observed with other electrofishing systems (Sharber and Carothers 1988). Pulsed direct current was applied to the water through two 40-cm diameter spherical stainless steel electrodes. The anode was suspended from the bow and the cathode from the stern of the boat. The combination of the CPS and spherical electrodes is believed to reduce voltage differentials and minimize injury to fish (Novotny and Priegel 1974; Norm Scharber, Coffelt Manufacturing, Inc., Flagstaff, Arizona, personal communication).

The CPS was normally operated at an output range of 200–250 V and 8–15 A. Water conductivity ranged from 832 to 1,103 $\mu\text{mhos/cm}$. The anode and cathode were interchanged after every hour of electrofishing to clean the cathode surface by reversing the electroplating process. Previous electrofishing efforts in Grand Canyon used a suspended live well with a Faraday shield to protect captured fish from further electroshock (Sharber and Carothers 1987). The SU-16 boat used in this investigation incorporated the live well into the internal frame design to eliminate the drag caused by the external live well and to enhance boat performance and maneuverability.

Space in the bow of the electrofishing boat generally permitted only one netter, as compared to two or more netters when using the larger 7-m craft in

previous electrofishing efforts in Grand Canyon (M. Yard, Glen Canyon Environmental Studies, Flagstaff, Arizona, personal communication). However, increased maneuverability of the SU-16 boat and added access to upstream locations and shallow shorelines outweighed the reduction of a netter. No loss in netting efficiency was seen with only one netter, primarily because the anode was located close to the boat where stunned fish were easy to capture. The netter controlled the safety footswitch to activate the electrofishing system, which enhanced safety and simplified communications with the boat handler.

Fish captured by electrofishing were placed in a live well and examined for evidence of injury (e.g., bruises, spinal deformity, prolonged lethargy). Humpback chub were transported within minutes to a central processing station on shore where they were measured, weighed, photographed, and tagged, then released near their original capture site to avoid biasing movement data. Nontarget species were measured, weighed, and released immediately. Passive integrated transponder (PIT) tags were injected intraperitoneally into humpback chub longer than 175 mm (overall length), enabling biologists to permanently identify individual juvenile and adult fish. PIT tags were evaluated for use on the Colorado River endangered fish (Burdick and Hamman 1992) and were first used on humpback chub in Grand Canyon in 1988 by the Arizona Game and Fish Department (C. O. Minckley, Arizona Game and Fish Department, Flagstaff, personal communication).

Of 11 fish sampling gears, electrofishing produced the highest catch rate for humpback chub—12.6 fish/10 h (Table). Electrofishing yielded 241 of 281 (86%) young-of-year, 60 of 77 (78%) juveniles, and 39 of 606 (6%) adults. Electrofishing accounted for 340 of 964 (35%) humpback chub captured. Although humpback chub did not have external bruises from electrofishing, one adult died after extended narcosis, and one juvenile was released with an apparent spinal deformity that may have existed before the electroshock.

Of 9,063 fish captured in Grand Canyon, 5,643 (62%) were captured by electrofishing. Bruise marks or spinal deformity were evident on 73 (1.3%), all of which were trout species. Of 3,013 adult rainbow trout (*Oncorhynchus mykiss*) captured by electrofishing, 62 (2.1%) had bruise marks, and 9 (0.3%) had spinal deformity. Of 601 adult brown trout (*Salmo trutta*) captured by electrofishing, 2 (0.3%) had bruise marks and none had spinal deformity. Three rainbow trout died as an apparent direct effect of electrofishing.

Nets, Traps, and Seines

Trammel Nets

Two inner-mesh sizes (2.5- and 3.8-cm² mesh) of trammel nets were used, each 22.8 m long, 1.8 m deep, and with 30.5-cm² mesh outer panel. The mesh was constructed of double-knotted 139 multifilament twine. Trammel

Table. Fish sample gear, total sample effort, and number and catch rates for humpback chub (*Gila cypha*) from the Colorado River in Grand Canyon National Park, October 1990–November 1991.

Sample gear	Total samples	Number				Catch rate ^b
		Y ^a	J	A	T	
Electrofishing						
220-V DC	762	241	60	39	340	12.57
Trammel nets						
22.8 m × 1.8 m; 2.5 cm, 30.5 cm-mesh	1,296	0	6	128	134	6.57
22.8 m × 1.8 m; 3.8 cm, 30.5 cm-mesh	1,394	0	0	271	271	12.11
Gill nets						
30.0 m × 1.8 m; 2.5 cm-mesh	723	0	1	102	103	6.76
30.0 m × 1.8 m; 3.8 cm-mesh	501	0	0	24	24	2.24
Experimental— 30.0 m × 1.8 m	311	0	7	34	41	6.36
Hoop nets						
0.6 m-hoop	44	0	0	2	2	0.35
0.9 m-hoop	14	0	0	0	0	0
1.2 m-hoop	36	0	0	2	2	0.43
Minnow traps						
42.7 cm × 22.9 cm	321	40	3	0	43	0.68
Seines						
3.0 m × 0.9 m; 0.3-cm mesh	24	0	0	0	0	0
Total	5,426	281	77	602	960	

^a A = adult; J = juvenile; T = total; Y = young-of-year.

^b Catch rate for electrofishing as fish/10 h; for trammel and gill nets as fish/30 m/100 h; for hoop nets, minnow traps as fish/100 h; for seines as fish/100 m².

nets were used to sample primarily eddies, pools, slow runs, and tributary inflows. Each net was secured to the shoreline and extended in the direction of, or slightly diagonal to, the current. Weights were tied to each end of the lead line, and a large white float was secured to the outer end of the net to facilitate retrieval. Small polypropylene-mesh gear bags were filled with rocks and used as net weights to avoid the need to carry heavy and bulky weights in the boats.

Each net was set for a maximum of 2 h to minimize stress to entangled fish and to rotate nets clogged by drifting filamentous algae, *Cladophora glomerata*. Clumps of this dislodged algae quickly accumulated and rendered the nets visible to fish and ineffective for sampling. Depending on river flow

(increasing flows carried greater volumes of algae), each net was rotated for cleaning after one to three 2-h sets. Nets were cleaned by spreading them on a beach for drying and by passing them through a specially designed cleaner with multiple brushes for dislodging the dry algae. Increased catch efficiency and reduced fish injury outweighed the time and effort required to clean these nets.

Trammel nets were the second most efficient gear for catching humpback chub. Catch rates varied between 12.1 (3.8-cm mesh) and 6.6 fish (2.5-cm mesh)/30 m/100 h (Table). The nets with 3.8-cm mesh accounted for 28% (271) of all chubs captured, and the nets with 2.5-cm mesh accounted for 14% (134). The nets with larger mesh (3.8 cm) captured only adults—271 of 606 (45%)—while the nets with smaller mesh (2.5 cm) captured 128 adults (21% of adults) and 6 juveniles (8% of juveniles). Only one humpback chub died of injuries received from a trammel net.

Gill Nets

Two mesh sizes of gill nets were used (3.8 cm² and 5.1 cm²), as well as experimental gill nets with four square mesh sizes of 1.3, 2.5, 3.8, and 5.1 cm. Each gill net was 30 m long and 1.8 m deep and constructed of double-knotted 139 nylon multifilament twine. The float lines consisted of 1.3-cm diameter braided polyfoamcore, and the lead line was made of 0.8-cm diameter leadcore. Gill nets were set, handled, and cleaned in the same manner as described for trammel nets. Although accumulation of filamentous algae was not as great as on trammel nets, fewer gill nets were used because of the greater risk of injury to the fish. Gill nets generally held the fish by the head and gill area—where an injury was more likely to be fatal—while trammel nets frequently entangled the body, resulting in less stress.

Catch rates for humpback chub captured with gill nets are presented in the Table. No humpback chub were lost of 168 caught in gill nets.

Hoop Nets and Traps

Hoop nets with 0.6-, 0.9-, and 1.2-m-diameter hoops were used. The 0.6-m-diameter hoop nets were 3.0 m long with 1.3-cm² mesh, the 0.9-m nets were 3.7 m long with 1.9-cm² mesh, and the 1.2-m nets were 4.9 m long with 2.5-cm² mesh. Each net had two 7.3-m wings of 2.5-cm² mesh. Hoop nets were set by anchoring the rear of the net to the substrate with a length of reinforcing steel bar or fence post and with the mouth oriented downstream to capture upstream moving fish. The opportunities for setting hoop nets in the main channel were limited to side channels, stable backwaters, and shallow shoreline runs. Hoop nets were checked every 4–8 h.

Two humpback chub were captured in each of the 0.6-m and 1.2-m hoop nets, for a catch rate of 0.4 fish/100 h (Table). No chub were captured in the 0.9-m hoop nets, and no chubs died from capture in hoop nets.

Minnow Traps

Unbaited minnow traps were used in small pocket waters, rocky shorelines, small backwaters, and small pools. The traps were commercial, 42.7 cm long and 22.9 cm in diameter, with openings at both ends and made of galvanized wire and steel. Minnow traps were tethered to a secure anchor point, flagged for easy location, and checked for fish every 4–8 h. These traps were limited in use by fluctuating river flows that quickly inundated or desiccated shallow shorelines. Nevertheless, 40 young-of-year and 3 juvenile humpback chub were captured in minnow traps—a total catch rate of 0.7 fish/100 h (Table). No known injury or mortality was caused to humpback chub by minnow traps.

Seines

Seines were used to sample shallow shorelines for young-of-year and juveniles fishes. Backwaters were not seined to avoid overlap with other investigators. The seines were 3 m long and 0.9 m deep, with 0.3-cm delta mesh. Although humpback chub were not captured with seines, many other native and nonnative species were caught.

Radiotelemetry

Radiotelemetry was first used to track humpback chub to determine movement and habitat use in Black Rocks, Colorado, in 1980–81 (Valdez and Clemmer 1982). Kaeding et al. (1990) radio-tagged humpback chub and roundtail chub in Black Rocks in 1983–85 to monitor movement and determine spatial spawning segregation. Radiotelemetry was implemented with humpback chub in Grand Canyon in our study in October 1990 to investigate the effects of Glen Canyon Dam operations on movement and habitat use.

Fifty-three adult humpback chub were radio-tagged from October 1990 through November 1991. Every 2 months, 3–10 adult humpback chub were surgically implanted with radio transmitters to maintain 5–10 active transmitters per month. Of 53 radio transmitters implanted, 6 weighed 9 g and 47 weighed 11 g. Four of the six fish with 9-g transmitters were monitored for 30–59 days (\bar{x} = 50.8 days); the other two entered the Little Colorado River (LCR) and could not be tracked because of high water conductance. Of 47 fish with 11-g transmitters, 43 were monitored for 56–147 days (\bar{x} = 99 days), and 4 were not contacted after they moved into the LCR. Only 1 of 53 radio-tagged fish died following surgical implant and initial tracking.

The radio transmitters were manufactured by Advanced Telemetry Systems (ATS), Inc. (Isanti, Minnesota), and weighed 9 g or 11 g. These were two-stage model BEI 10-18 number-1 transmitters with an 11.5-cm long external whip antenna of teflon-coated stainless steel. The 9-g transmitters

were 3.8 cm long and 1.3 cm in diameter, and the 11-g transmitters were 7.5 cm long and 1.3 cm in diameter. Radio frequencies of 40.600–40.740 MHz were used, separated by 10-Hz intervals (i.e., 40.600, 40.610, 40.620, etc.). The combination of 15 different frequencies and 3 pulse rates (40, 60, or 80 pulses/min) allowed for 45 unique transmitter signatures to identify individual fish. Frequency and pulse rate combinations were reused following expiration of the original transmitter, which was about 50 days for 9-g transmitters and 90 days for 11-g transmitters.

To avoid affecting behavior of radio-tagged humpback chub, maximum weight in air of the transmitter did not exceed 2% of the body weight of the fish. Thus, 9-g transmitters were implanted in fish weighing 450 g or more, and 11-g transmitters were implanted in fish weighing 550 g or more. Larger transmitters weighing 13 or 15 g would have longer duration, but few fish were available that weighed 650 or 750 g. Each radio transmitter was surgically implanted into the peritoneal cavity of the fish according to the procedures described by Valdez and Nilson (1982) for humpback chub and modified to accommodate the external antenna. The transmitter rested on the pelvic girdle of the fish with the antenna protruding posterior to the pelvic fin. The trailing antenna was clipped even with the hypural plate to prevent fraying of the caudal fin by movement of the antenna.

Radio transmitters (13 g with internal antenna and 9 g with external antenna) were tested by Yard et al. (1990) in the Colorado River in Grand Canyon, and transmissions were received from 57 m away at a maximum depth of 2.4 m and at 860 μ mhos/cm water conductance. Transmissions from these same transmitters in the LCR were received from only 3 m away at a depth of 0.9 m and at 4,630 μ mhos/cm water conductance. Our tests showed that radio signals from 11-g external antenna transmitters were received from 50 m away at a maximum depth of 4.5 m and from 1,200 m away at a depth of 1 m.

Radio-tagged fish were relocated and monitored with the aid of two brands of radio receivers—a model 2000 ATS programmable receiver and a Smith-Root SR-40 simultaneous scanning search receiver. A Larsen-Kulrod omnidirectional antenna was used with each receiver to search for the first radio contact, then the ATS receiver with a directional loop antenna was used for locating the fish. Most tracking was done from boats and from the shoreline. Aerial tracking was conducted three times to evaluate long-distance movement but was unnecessary because there was little movement from the release sites.

Cold water temperatures may have caused variations in transmitter frequency and pulse rate. Radio frequency, using the same radio receiver, varied as much as 2 Hz. Pulse rates (pulses per second) of 15 of 29 transmitters varied by more than 10%, and pulse rates of 2 transmitters varied by more than 20%. These variations in radio frequency and pulse rate did not interfere with identifying individual fish.

Discussion

The sport utility SU-16 boat and the sport heavy duty SH-170 boat were considered major assets in this investigation. These boats increased access to various habitats, provided biologists with opportunities to sample more areas, and allowed development of a better understanding of the life history and ecology the native fishes in Grand Canyon. The boats enabled biologists to revisit sites upstream and downstream from base camps, enhancing the scientific validity of the investigation by allowing replication of data collection. Boat speed and maneuverability increased sample efficiency and enabled biologists to check 6–10 nets every 2 h. The boats required skilled handlers and prescribed precautions to prevent personal injury and equipment loss.

The electrofishing systems on these small research boats accounted for 86% of the young-of-year and 78% of the juvenile humpback chub captured but only 6% of the adults. We believe this sampling method to be the most reliable for catching preadult humpback chub. Electrofishing caused visible bruises or spinal deformity on 1.3% of trout captured but caused the death of only one humpback chub. We considered this incidence of injury acceptable because of the benefits gained from using electrofishing in this investigation.

Trammel nets with 3.8-cm mesh produced the highest catch of adult humpback chub (45%) of the 11 gears evaluated. Trammel and gill nets with 2.5-cm mesh and experimental gill nets yielded nearly identical high catch rates, indicating that these nets are the most reliable sample methods for capturing adult humpback chub. Gill nets with 5.1-cm mesh produced only 2% of the chubs captured and were not considered effective because the mesh was too big to hold the fish.

Minnow traps were the only other gear, besides electrofishing, that yielded young-of-year chubs. The traps were easy to handle, maintenance-free, and did not require frequent checking. When strategically set at times and places likely inhabited by young chubs, they were effective at assessing occurrence, relative density, habitat use, and associated species. Hoop nets and seines, however, were not effective at catching humpback chub in the mainstem.

Radiotelemetry showed great utility in describing movements and habitats of adult humpback chub. Radio-tagged fish seemed to behave normally as indicated by subsequent recaptures and spawning ascents into the LCR. These outmigrations from the mainstem were confirmed by concomitant decreased catches of chubs in mainstem gill and trammel net sets. Maximum radio transmission depth of 4.5 m provided an opportunity to evaluate vertical movement of radio-tagged fish by measuring time with signal reception (fish was above 4.5 m depth) and time with no signal reception (fish was below 4.5 m depth). Thus, radiotelemetry enabled us to assess horizontal and vertical movement and habitat use, as affected by flow, turbidity, time of day, and season.

The equipment and methods implemented in the Colorado River in Grand Canyon proved effective in sampling the ichthyofauna of this whitewater region. These methods will require continued modifications and refinements to better adapt them to the conditions in Grand Canyon. More important is the need to have trained and experienced biologists and boat handlers. Where travel alone is arduous and hazardous, experienced personnel are vital for proper operation of sampling equipment and reliable data collection to maintain scientific validity.

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